CHAPTER 2

STREAM CHANNEL MODIFICATION AND ASSOCIATED ENVIRONMENTAL EFFECTS

2-1. Channel Modification Designs. The basic concept of all flood control channel designs is to reduce flood area and duration by providing a smoother, steeper, or larger channel than the existing stream. Design capacity criteria vary based on project settings. Projects in agricultural areas are often designed to reduce flood durations during planting, growing, or harvesting seasons, while urban channels are typically designed to eliminate flooding in the protected area for all floods smaller than or equal to design events. Several types of channel modifications are commonly used to achieve project purposes, and most projects include several types of channel designs that vary from reach to reach. This chapter discusses some potentially deleterious effects of channel modifications, and designers aware of these effects can mitigate them. Potential environmental problems can be brought into the open, when trade-offs are being made during project formulation discussions with local interests.

a. Clearing and Snagging. Clearing refers to removal of woody vegetation and debris from channel banks and adjacent areas, while snagging refers to the removal of debris, logs, and boulders from the channel. Clearing and snagging are sometimes employed as individual techniques and are normally required for other types of channel modification. Hydraulic effects of clearing and snagging tend to be short lived relative to other types of modification, and cleared and snagged channels often require frequent maintenance or reworking.

b. Excavated Channels. Natural channels are often straightened, enlarged, or both to increase flow capacity or to allow for placement of other structures. Diversion channels are sometimes constructed to provide a separate path for high flows to a receiving water body and to supplement channel capacity. Excavated channels traditionally have had straight alignments and trapezoidal cross sections, although more complex designs are being used with increasing frequency. Channel excavation often requires significant clearing to allow for channel rights-of-way, equipment access, and placement of exca vated material. Dry excavation techniques, draglines, clamshells, and hydraulic dredging are all commonly used for channel excavation. Straightened channels often include features such as grade control structures, slope protection, or paving to prevent channel erosion and instability. Slope protection and grade control structures are also sometimes used on natural or slightly modified channels to control bed and side slope erosion.

c. Paved Channels. Channels designed to carry high-energy flows are frequently paved with nonerodible material, usually reinforced concrete. Paved channels are expensive to construct and are accordingly limited to areas with steep topography or where land costs are high. Concrete channels sometimes have rectangular cross sections to minimize land requirements.

d. Side Slope Protection. Side slope protection is incorporated into channel design when erosive velocities are expected to occur and is widely used to prevent erosion along natural channels. WES Technical Report (TR) E-84-11 and Allen (1978), Keown et al. (1977), and Office, Chief of Engineers (OCE) (1978, 1981c) (see Appendix A) contain thorough reviews and descriptions of side slope protection methods. Methods may be categorized as continuous or intermittent, with riprap revetment as an example of continuous protection while groins and hard points are intermittent designs. Vegetation and rock riprap are two of the most common materials for slope protection, but gabions, tires, soil stabilizing chemicals, and other materials are sometimes used. Construction of slope protection usually involves clearing for access, slope grading, and placement of the protective materials or structure.

e. Erosion and Sediment Control Structures. Several types of structures have been used to control scour and deposition in natural and modified channels.

(1) Grade control. Degradation of the channel invert may be prevented by placing concrete, stone, or sheet piling stabilizer sills across the channel invert. Stabilizers usually do not extend above the channel invert. Drop structures may also be used to provide sudden changes in channel invert elevation without erosion. Drop structures are used to reduce the gradient of the main channel and to admit tributary inflows to a deepened main channel without headcutting. Generalized sketches of stabilizers and a grade control structure are presented in EM 1110-2-1601.

(2) Debris basins and check dams. Debris basins and check dams are sometimes built upstream of flood control channels to trap large bed-load debris. Sediment basins are sometimes used in a similar fashion to trap smaller sediments. This is done to prevent damage to channel linings, aggradation of channels, and deposition at stream mouths. The storage capacity of debris and sediment basins must be maintained by reexcavation after major storm periods.

f. Culverts. Concrete channels are covered at street crossings and in some intensively used areas, thereby forming box culverts. Corrugated metal or reinforced concrete culverts are used to pass flow through embankments such as roadfills. Culverts sometimes develop problems with debris blockage or downstream scour. (See ER 1165-2-118 on covered flood control channels.)

g. Levees and Floodwalls. Levees are earthen embankments that provide flood protection from seasonal or infrequent high water. In urban areas where land costs are high, concrete or masonry walls may be used instead of levees since they require so much less space than a sloped embankment. Sometimes floodwalls are constructed on top of levee embankments. Both levees and floodwalls are frequently used in concert with various types of channel modification. Levee construction usually requires clearing to allow for earthmoving equipment access, excavation of borrow areas, and placement of the embankment. After construction, levee side slopes are seeded or sodded, and vegetation on levees is carefully maintained to avoid conditions that might impede inspection or endanger structural integrity of the levee during floods.

2-2. General Environmental Effects. Environmental effects of channel modification are difficult to categorize because they are interrelated in complex ways. In general, effects may be categorized according to the nature of the affected resource: aesthetics, recreation, water quality, terrestrial habitat, and aquatic habitat. Effects may also be considered primary, secondary, or tertiary. For example, straightening a particular hypothetical channel results in rapid bed and bank erosion (primary impact), which degrades downstream water quality due to increased levels of suspended sediment (secondary impact), which adversely affects the aesthetics and aquatic habitat (tertiary impacts). The effects of channel modification on water chemistry, and particularly the biotic community, are difficult although not impossible to measure. Effects on aesthetic and recreational resources are difficult to quantify, and perception of significance varies from individual to individual. Typical physical changes and environmental effects due to channel modification without environmental consideration are depicted in Figure 2-1. Most channel projects do not begin with natural unaltered streams; hence, the designer may have the opportunity, particularly in urban settings, to greatly improve the stream's environmental conditions. A literature review of the environmental effects of channel projects is provided by Swales (1982).

2-3. Effects of Snagging. Effects of snagging apply to all channel projects except for clearing performed without snagging, which is extremely rare. Snagging may have a positive effect on aesthetic and recreational resources and is occasionally performed to improve boating access. The main effects of snagging relate to aquatic habitat.

a. Invertebrates. Removal of snags usually allows deposits of leaves, twigs, and fine-grained sediments to be swept downstream. These deposits are key habitat and nutrient components for many invertebrates (fish-food organisms). In streams with sandy, shifting beds, snags and the organic debris they trap are the only suitable substrate for many species.

b. Fish. Snagging reduces the area of structures used by both forage and predator fish for cover, orientation, and territoriality. This similarly reduces the total substrate available for primary producers (e.g., algae and mosses) and some invertebrates.

2-4. Effects of Clearing. Limited clearing and debris removal can improve aesthetics and recreational opportunities, but removal of all woody riparian vegetation often has a net detrimental effect on aesthetics and recreation. Major effects of clearing have to do with alteration of terrestrial habitat in the valuable riparian zone. A literature review of the environmental effects of clearing and snagging can be found in WES TR E-85-3.

a. Water Quality. Water quality eff cts of clearing are mostly due to reduced shade and, accordingly, are most significant for small channels. Shade removal may result in increased water temperatures and increased levels of in-channel photosynthesis, which may produce secondary water quality impacts such as diel changes in dissolved oxygen and pH.

b. Terrestrial Habitat. Streambanks and associated vegetation are extremely productive and valuable habitats due to the rich supply of nutrients and moisture, the "edge effect" between the riparian zone and the adjacent upland on one side and water on the other, and the diversity of physical conditions created by channel migration and vegetative succession. The elongate shape of the riparian zone creates a high edge-to-area ratio and often

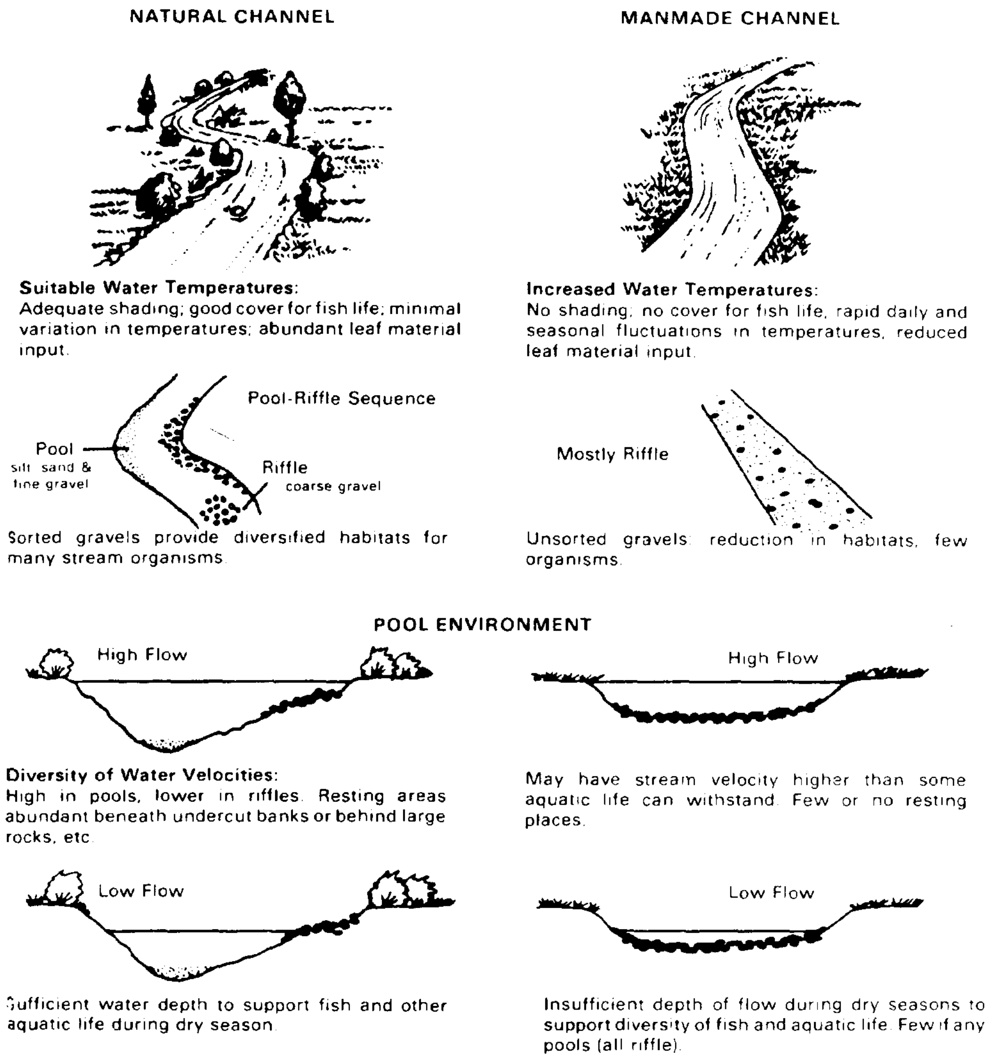

Figure 2-1. Typical physical changes and attendant environmental impacts due to channel modification without environmental design components (from Nunnally and Keller 1979)

provides a natural corridor through developed areas. In prairies and deserts, riparian zones provide an extremely sensitive, scarce, and valuable type of habitat. Removal of riparian vegetation by clearing for channel construction or maintenance, by induced land use changes, or by natural succession caused by drier conditions results in adverse impacts upon dependent faunal species. Long-term effects depend on the extent and frequency of maintenance and the rate of vegetative succession.

c. Aquatic Habitat. Removal of riparian vegetation results in reduced inputs of leaves and twigs, which are important as a food base for some aquatic organisms, and increased in-channel photosynthesis (if photosynthesis is light limited). These changes can shift the aquatic ecosystem from a heterotrophic to an autotrophic state, at least for small streams in the northeastern and northwestern United States. Loss of overhanging vegetation also removes hiding cover for fish.

d. Other Effects. Shade removal may result in invasion of the channel by rooted plants at low flows, which can increase hydraulic resistance and reduce flow capacity. Clearing can also reduce bank stability and result in increased bank erosion, depending on local soil characteristics and channel velocity.

2-5. Effects of Channel Excavation. The primary effects of channel straightening and enlargement are usually the removal of riparian vegetation and changes in channel stability and in the hydraulic and hydrologic regime. Clearing may be reduced adjacent to enlarged channels as a result of the reduced flood risk. Additional information is available in WES TR E-82-7 and WES TR E-85-3. Effects associated with clearing are addressed in paragraph 2.4 above.

a. Channel Instability. Improperly designed excavated channels can experience problems with rapid scour of bed and banks, unwanted sediment deposition, and increased sediment loads. Channel instability increases maintenance costs, degrades water quality and habitat, and may result in damage to bridges and utility crossings.

b. Hydrologic and Hydraulic Effects. Hydrologic and hydraulic effects of channel projects vary widely and can be divided into primary effects, which are intentional, or at least anticipated (e.g., lowered water tables and decreased overbank flooding), and side effects, which are unintentional and usually not anticipated (e.g., more rapid water-level fluctuations, wetland drainage, greater variation of discharge, and increased downstream flood storage). These side effects are usually not well documented. For example, drier conditions on nearby floodplains and contiguous wetlands can result in induced land use changes or shifts in floral and faunal communities. Large increases in mean and maximum velocity or decreases in mean and minimum depth can be extremely detrimental to aquatic organisms.

c. Aesthetics. The aesthetic value of a project area is determined by the combination of landscape components (e.g., landforms, vegetation, and land use), climatic factors, and human perceptions or expectations. The significance of aesthetic effects is a function of changes in landscape components caused by a project and factors related to frequency of viewing and project setting. Modified channels sometimes present a uniform, artificial appearance characterized by straight lines and early-successional stage vegetation. On the other hand, a channel with an overall uncluttered appearance and graceful bridges may be more harmonious with some urban settings than the eroded, debris-laden stream that preceded it. Aesthetic impacts tend to be most severe for channels with straight alignments, extensive clearing, or instability problems.

d. Recreation. Channel excavation effects on recreational resources can be positive or negative and are related to changes in channel depths and velocities, water quality, access, and aesthetics. Habitat changes affect consumptive and nonconsumptive uses of fish and wildlife.

e. Water Quality. Water quality changes associated with channel excavation vary widely from site to site. Many projects are located in urban areas and exhibit poor quality prior to channel excavation. Improved flood control sometimes encourages expansion of agricultural and industrial activities that may in turn contribute to degraded water quality. Turbidity generally increases during construction. Temperature can be expected to increase if shade is removed from a long reach that is narrow enough to be mostly or totally canopied. Dissolved oxygen concentrations may increase or decrease, depending on the effects of channel modification on temperature, photosynthesis, and reaeration.

f. Terrestrial Habitat. Major effects of channel excavation on terrestrial habitat are related to clearing and induced land use changes in riparian zones (see paragraph 2-4). Improved drainage and water table lowering caused by channel excavation can adversely affect wetlands some distance from the channel.

g. Aquatic Habitat. The effects of channel straightening and enlargement on aquatic habitats are similar to those associated with snagging and clearing (described in paragraphs 2-3 and 2-4). In addition, channel straightening without preservation of meanders may result in a reduction in the quantity of aquatic habitat, sometimes by as much as 50 to 60 percent. Even when cutoff meanders are left in place to provide habitat, if not properly designed they often gradually drain, fill with sediment, or undergo water quality degradation. Channel enlargement projects may induce flow interruptions during dry periods with resulting impacts on aquatic communities.

(1) Benthic macroinvertebrates. Benthic macroinvertebrates have been observed to recolonize modified reaches rapidly if water quality and substrate in the modified reach are favorable. Channel projects that do not destroy the armor layer or reduce the overall bed material (substrate) size provide a more suitable benthic habitat. Sandy bed material tends to be shifting and unstable and have low benthic macroinvertebrate density.

(2) Fish. Fish populations in enlarged or straightened channels tend to be more uniform in age and size than in unaltered streams, with smaller sizes dominating. Fish species diversity, density (both numbers and biomass), and catchable game fish numbers and biomass tend to decline following channel modification. These effects on fish populations are due to the more uniform depths, velocities, illumination, and substrate and to the loss of cover. Impacts on coldwater streams tend to be more severe than for warmwater streams, which is expected due to their lower species diversity.

2-6. Effects of Channel Paving. Paved channels tend to be accompanied by most of the impacts associated with snagging, clearing, and channel excavation, and tend to have additional detrimental effects on aesthetics, water quality, and aquatic habitat. Parrish et al. (1978) summarized studies of the effects of concrete channels in Hawaii on water quality and aquatic biota, and many of their conclusions have general applicability.

a. Aesthetics. Conventional reinforced concrete linings present an artificial, unnatural appearance relative to a natural stream channel. Straight lines and uniformity of form, texture, and color are less desirable than the visual diversity offered by most natural meandering channels with vegetated banks. In some cases, the appearance of a lined channel may be perceived as an improvement over a severely degraded setting characterized by caving banks, solid waste, debris, etc.

b. Water Quality. Some lined channels have been observed to experience much greater maximum water temperatures and ranges of diurnal fluctuation of water temperature than nearby natural streams. These effects are often due to the wide, shallow flows; lack of shade; solar heat transfer by the lining material; and focusing of solar energy by the vertical walls. Other water quality parameters are affected by temperature. Algae growth may occur on unshaded channel bottoms and can raise pH levels and increase dissolved oxygen concentrations during the day. The stability imposed by channel lining can decrease levels of suspended solids and turbidity.

c. Terrestrial Habitat. In addition to the effects noted in paragraphs 2-4b for clearing and 2-5f for channel excavation, paved channels with extremely steep, smooth sides can be impassable for some terrestrial animals. Access to and across the channel may be prevented, and animals that fall into the channel may be trapped.

d. Aquatic Habitat. Effects of channel paving on aquatic habitat are related to effects on water quality, substrate, and hydraulics. Water quality effects (paragraph 2-6b) can eliminate species or groups of species. The channel lining itself is a radical departure from the natural bed material that serves as substrate for benthic organisms. Many fish species are also affected by substrate changes since they feed upon the benthic organisms and require certain types of substrate for spawning. Flows in paved channels tend to be extremely shallow at low to normal discharges and extremely rapid at high discharges. These conditions may be unfavorable to some populations of aquatic species.

2-7. Effects of Side Slope Protection. The environmental effects of slope protection are related to the amount of clearing required and the type and extent of the protection works. Completely stabilized channels are no longer free to migrate laterally and to develop diverse terrestrial and aquatic habitats. Vegetative succession proceeds without interruption from channel movement, and no new backwater areas are formed to replace those lost to the natural processes of sedimentation. Available information regarding environmental effects of slope protection is reviewed in WES TR E-84-11.

a. Aesthetics. Most observers perceive the visual contrast between the natural environment and most types of slope protection works as undesirable. The degree of visual impact depends on the type of structure, the materials used, and the amount of revegetation allowed. In some cases, revegetation can completely obscure slope protection structures after a few growing seasons, minimizing the visual impact of the structure.

b. Recreation. Depending on design, slope protection can aid or hinder access to the water s edge for recreation or sightseeing.

c. Water Quality. Water quality impacts of slope protection tend to be similar to the effects of clearing (paragraph 2-4a). In addition, suspended solids and turbidity levels tend to increase during construction, but these decrease after construction is completed and side slopes are stabilized.

d. Terrestrial Habitat. Construction of slope protection has effects on terrestrial habitat similar to those from clearing (paragraph 2-4b). Slope protection structures may hinder wildlife access to the channel and preclude use of banks for denning. Vegetation cleared during construction can sometimes be replaced by natural invasion. At other times, plantings may be required to ensure development of particular plant communities to achieve specific objectives.

e. Aquatic Habitat. Slope protection can have both positive and negative effects on aquatic habitat. Grading and placement of continuous protection destroys habitat diversity provided by physical features such as snags and undercut banks, which are used by fish for protective cover. Stone and other materials provide stable substrate readily colonized by many species of benthic macroinvertebrates. Stabilization of adjacent substrate provides additional habitat for burrowing benthic species. Protection can reduce suspended sediment concentrations and turbidity levels detrimental to aquatic species. On small streams, removal of overhanging riparian vegetation can reduce shading and cause increases in water temperature and photosynthetic activity. Placement of noncontinuous, intermittent structures projecting into the stream creates protected slackwater habitat on the downstream sides of structures and encourages deposition of stabilized substrate.

2-8. <u>Effects of Sediment Control Structures and Culverts</u>. By stabilizing the channel and preventing rapid transport of large volumes of sediment, sediment control structures usually have positive effects on aesthetics, recreation, water quality, and aquatic habitat. Adverse impacts are related to the appearance of the structure and blockage of migration routes.

a. Aesthetics. Sediment control structures may improve or degrade aesthetic resources, depending on the degree to which they are visually compatible with their settings in terms of the scale of the structure and the color and texture of the materials used.

b. Recreation. Some drop structures provide the opportunity for inclusion of water recreation features such as boatways. However, drop structures and culverts can be barriers to boaters or canoeists and should be designed and managed to avoid hazards to boaters, waders, and swimmers at high flows.

c. Aquatic Habitat. Culverts may block fish migration due to their length, the vertical drop in the water surface at the downstream end, poor approach conditions, or flow conditions within the culverts. Drop structures can similarly block fish passage. Extremely long culverts represent a loss of aquatic habitat due to the lack of illumination and natural substrate.

2-9. <u>Effects of Levees and Floodwalls</u>. The primary environmental effect of levee systems is the creation of drier conditions on the protected floodplain, which frequently leads to land use changes. If the natural channel is unaltered and some riparian habitat is preserved between the levees, levees can have less adverse effect on habitats than do other types of channel modification. Reduction of the extent of floodplain inundation may affect the spawning success of some species.

a. Aesthetics. Levee embankments and floodwalls are normally massive and uniform, with rigid, straight lines. Views of the leveed stream are often blocked. However, levees may add visual diversity to floodplains devoid of topographic relief and provide scenic overlooks of the river and riparian area.

b. Recreation. Levee projects can improve access to the leveed stream and riparian lands and lend themselves well to several types of recreational development such as trails or fishing in borrow pits. Floodwalls without pedestrian openings can hinder public access to the water edge.

c. Terrestrial Habitat. Substantial amounts of clearing are sometimes required for embankment construction, borrow areas, and access. After construction, the usual practice is to allow only uniform sod with grass 2 to 12 inches high to grow on the levee embankment, which is of value only to species inhabiting open areas. The levee produces drier conditions on the landside. Land use changes, such as clearing for agriculture, may be induced on the landside, while the changed regime between the levees alters plant and animal species. In general, the deeper and more prolonged flooding and the wider range of flow fluctuations will restrict the development of ground cover and temporarily alter habitats of dependent animal species such as ground-dwelling mammals.